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Taken from article in Russian "Automation and Instrumentation", 1960, pages 34 through 38, and translated by A. V. Stavrakis.

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Character Tracing System for an Automatic Reader

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Considering that the input devices of a modern computer are still in a development stage and inadequate (input is slow and requires a considerable amount of mechanical labor), the problem of developing an Automatic Reader is essential.

Automation of the input device is extremely essential in the case where large numbers of documents are to be processed, for example, bank accounts or mechanized translators.

Up to now, little effort has been accomplished in this field.

A majority of the described devices have the purpose of recognising characters, or numbers of a particular, standard, size and style (Reference "Electrical Engineering" 29, #250, 180-190, 1957).

However, the major interest would be in developing an Automatic Reader capable of resolving letters or numbers (characters) regardless of their size or style with possible defects present in the printing to be read.

Basic Principle of the Automatic Reader

The principle of the Automatic Reader presented herewith permits science to come closer to solving the problems of character recognition regardless of their size and style or order in which they are located.

The principle of the Reader is based on the following:

1. Tracing System
2. Direction Analyzer
3. Memory

The photo-electric digital scanning system directs an electron beam, in the scanner, to trace the contour of the character following the outside border of the character land.

The motion of the tracing beam consists of a number of discrete steps of <u>equal size</u>.

The numerical (digital) automat, or so called directional analyzer recognizes at each instant of time the average direction of motion of the electron beam for some number of "<u>steps</u>" it has made in the past.

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The average direction of the scanning sweep is compared at intervals of time against eight predetermined directions spaced 45° apart. The one predetermined line nearest the average direction of the scanning sweep, for each interval of time, is selected in the analyzer. During each "step" the analyzer originates a code for the average direction of motion of the electron beam.

From all of the sequences of recognized codes, (average directions only,) the "balanced" sequences are registered.

("Balanced" sequences are considered to be the ones which repeat themselves during a number of "steps" of the scanning system).

The analyzer analyzes all the code groups previously generated and assigns codes to only new direction chances.

(Summing all identical previous coded segments and producing one code for each direction.)

The resulting sequences of codes after previous cancellation for the basic directions, can serve as a code group for the recognition of the character scanned.

This sequence of codes (code group) is compared with samples retained in the memory.

On the basis of such comparisons the analyzed symbol is selected as one of the characters in the alphabet, and the Automatic Reader puts out the code for that symbol.

It is assumed that a Reader built on this principle can be used to read different alphabets.

For that purpose, sample symbols for each character of a given alphabet should be fed into the Reader synchronously with their code. (In other words, the coded symbols which must appear on the output of the Automatic Reader as a result of a comparison with a selected symbol.)

The construction of the character, on the output of the device, is the same as the reading or scanning process, which involves following the contour of the sample character.

During that "follow-up" or scanning, the sequences of codes of the basic directions developed by the analyzer, are registered in the memory, together with the code of the symbol (character).

Repeating simultaneously, the above described procedure for all symbols of an alphabet, the memorized symbols are being used as samples during the read-out comparison for their recognition.

In this memorandum, the authors do not attempt to describe and analyze the Automatic Reader in all its functions.

Such analysis is feasible only after a device of this kind is built and tested. In this work, a detailed analysis of only a numerical (digital) tracing system is described.

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This digital reader has been built and successfully tested by the "Computers Center of the Academy of Sciences in U.S.S.R." This system by itself can present a significant interest.

A Two Ordinate Numerical (Digital) Tracing System

A tracing system of an Automatic Reader must make certain that the beam, of the electron-tracing tube is tracing, or following, the outside contour of the character image, i.e., moving along the border of the black and white fields.

This tracing system differs from the usual concept in which the motion of the electron beam is in only one direction.

The proposed tracer controls the electron beam in two directions.

This system cannot be replaced by two single motion systems, because the ordinates of points along the contour of the character cannot be interpreted in a simple manner. They (the ordinates) cannot be presented as a single function of time, or any other independent variable. Descriptions of that type of tracing systems do exist in literature. It was proposed for an automatic duplicating (copying) of drawings on paper of simple contours.

* Reference. J. Loel, "Communication Theory"/London 1952 Symposium/317-327, London 1953. In this system a beam of light is moving continuously in a circle, intersecting the contour of the line being traced . The signals which are being generated by the photocell during intersection of the traced line operate two (2) electrical motors. Depending on the phase of the signals and the phase of the light beam moving in a circle, the motors move the center of the circle, together with the reading mechanism. This motion is controlled in such a manner that the center of the circle tends to follow the contour of the line at all times.

Such a system completely solves the existing problem.

Though this system is based on a continuous duty cycle of the tracing operation, correlating such a system with digital information of any kind may create unnecessary problems. In addition, a continuous duty cycle for a tracing system unavoidably requires a solution to fairly complicated problems in respect to stabilization and quality of tracing. In a digital system these problems are solved considerably easier.

As described above, it is reasonable to develop a tracing system for an Automatic Reader in a digital form. In that system, the input signals are digits (separate bits of information). The tracing motion consists of individual "steps", and control of the motion is achieved through the digital automat.

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Basic Logic for Tracing

As a basic approach for a digital tracing system, certain principle rules should be developed. The scanning beam motion should follow these rules assuring a positive motion along the outline of the character.

Due to the fact that the system is to be digital (binary), the motion of the beam must be broken down and "steps" of equal size with a predetermined direction. Based on this principle, the beam can follow the contour of any line.

The number of these basic directions should be more than two (2).

It is absolutely necessary that the system be informed, at any instant of time, of the relative location between the scanning beam and the closest portion of the border line, between the black and white fields.

In order to achieve that requirement, besides the main tracing beam, it is necessary to have a number of secondary so called "Probing Beams". These probing beams are supposed to move together with the main beam and give information on the location of the traced borderline. The probing beams guide the direction of future motion of the main beam.

However, from a technical point of view instead of the Probing Beams, it is much easier to have the main beam "follow-up", in a certain sequence, all the points where the Probing Beams are supposed to be. In this case, the information received during such a "follow-up" must be remembered and stored for a short period of time.

(In other words, the guidance of the main beam must be performed by the digital automat).

"Non-Primitive" Schematic

The logic of the tracing system should guide the main beam in such a fashion that it would pass through all "Probing" points and at the same time retain uniform motion along the border of the line. The most simple and yet, at the same time, fairly advance logic for a tracing system consists of the following:

1. First Rule

   The tracing beam has a possibility to move in four basic directions, i.e., up, down, left or right in steps of equal size.

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2. Second Rule

After completion of each "step", the direction of motion changes in such a way that the final motion of the tracing beam follows the sides of a square.

3. Third Rule

The beam has a clockwise direction of motion over the black background and counter-clockwise direction over the white background. The motion of the tracing beam (based on the above principles) is shown in figure 1.

The logic (based on the above principles) is economical due to the fact that the beam is making a minimum number of steps (motions) in order to obtain the necessary information for locating the border of the traced lines.

It is easy to evaluate the accuracy or quality of the tracing technique resulting in the beam never moving away from the traced line more than $1\frac{1}{2}$ steps.

The question of stability of motion requires a more detailed analysis. It is not difficult to realize that a stable tracing beam and character, free of outisde interference follows any configuration of the contour of the line to be traced and cannot distort the line more than $1\frac{1}{2}$ "steps".

However, in case outside interference is present, the stability is lost and the beam starting at some instant of time can possibly start moving in the prescribed "square" manner without intersecting the character border. (See figure 2.)

This phenomena was observed during the experimental work using a tracing device operating under the above mentioned principles.

If for any reason, step #1, indicated on figure 3 by "O", is slightly longer than normal, and step #2 shorter than normal, the tracing beam will not intersect the character during step #3, and even during any future motion of the tracing beam. For these reasons, there cannot be developed an adequate system insuring stabilized motion by trying to stabilize the step size.

However, a simple change in the previously described logic can assure stability.

This change is that if the beam does not intersect the contour of the character during two adjacent steps it would circle around the spot where the last intersection occurred.

To be able to accomplish such a change in logic, the second basis rule must be modified to be:

"If, during the two adjacent steps, no intersections, between beam and contour occurred, and during the time before such next intersection does occur, directional changes of the beam must follow each uneven number of steps". The step which made the last intersection is considered to be the zero (0) step.

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In other words, starting from some instant of time the beam starts moving along a square which side is doubled in size. If a displacement of the beam, or character occurs because of interference and does not exceed the size of one "step" during a length of time corresponding to eight steps, the tracing beam must again intersect the character border.

The actual testing analysis proved that systems operating by such modified logics are stable.

Schematic of a Tracing System

A tracing system operating on the principle described above is shown in figures 4 and 5.

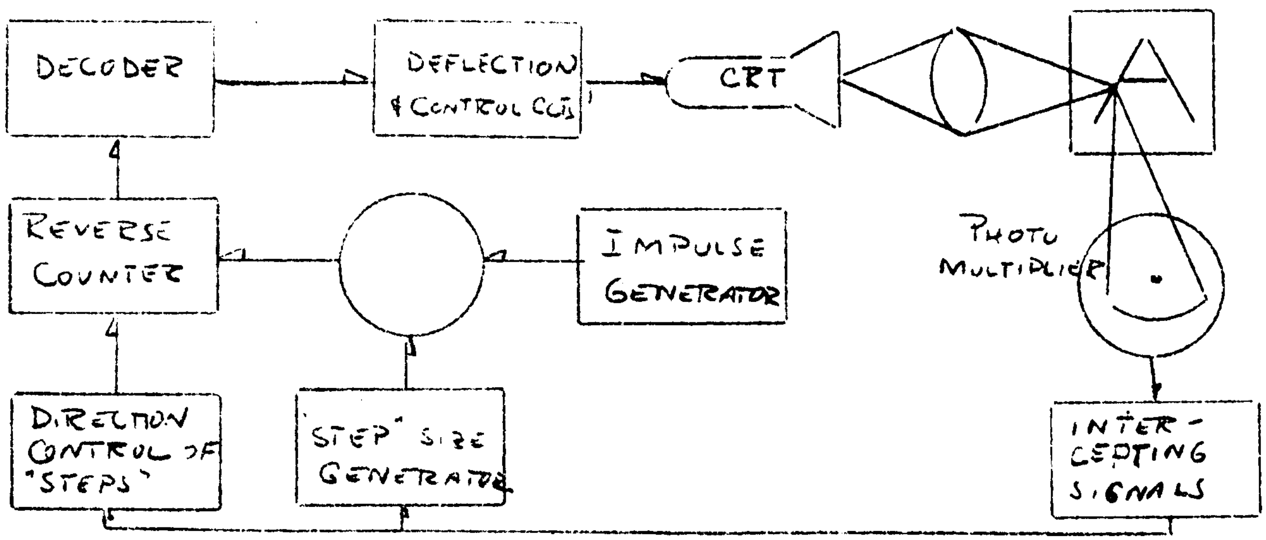

Figure 4

A reduced image size of the CRT screen face is projected on a sheet of paper through an optical system. On that paper characters are printed. By doing this, the image of a light dot on the screen of the CRT projects on the dark land of the character or on the white background of the paper. The reflected light from the paper is projected onto the cathode of a photo-electric multiplier. The intensity of that reflected light depends on where the light dot is located at that instant of time. The output pulse from the photo-electric multiplier operates a "non-symmetrical trigger" in such a manner that during each change from white to black, or vice versa. The "non-symmetrical trigger" (flip-flop??) changes its condition.

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The "non-symmetrical trigger", together with two pulse generators (one shots??) develops a "block" which generates the signals during the border intersection.

This "block" has two outputs. One of them generates a pulse by crossing from white to black and the other from black to white.

These signals are used as input signals for a device which directs the motion of the beam.

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.05 Tr. 2.0 мм
.1мм To [illegible]

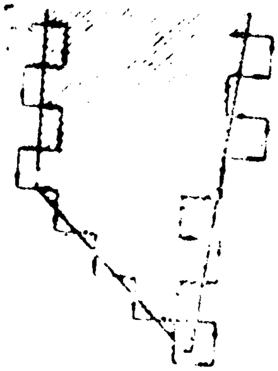


Рис. 1 [illegible] луча [illegible] ницы

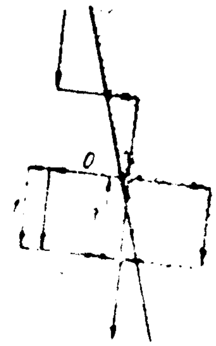


Рис. 2 Неустойчивое движение при колебаниях длины шагов

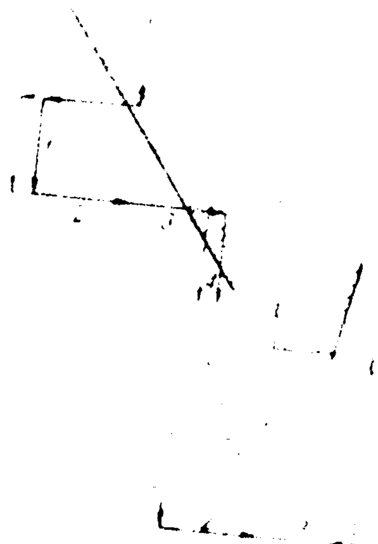


Рис. 3 [illegible] движение в соответствии с [illegible] алгоритмом

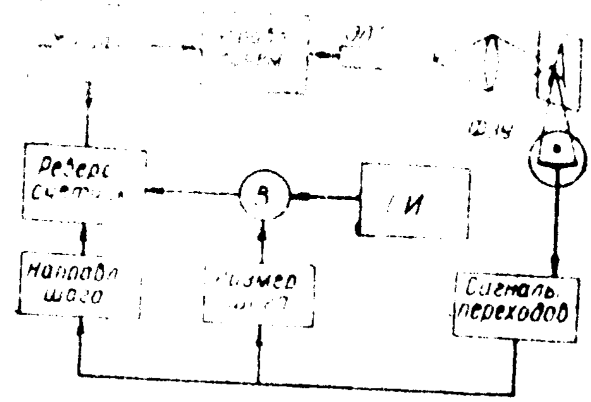
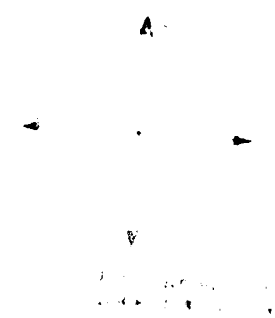
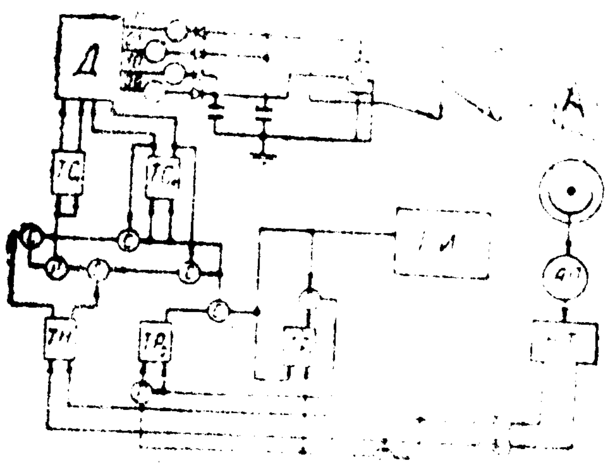


Рис. [illegible] схема следящей системы





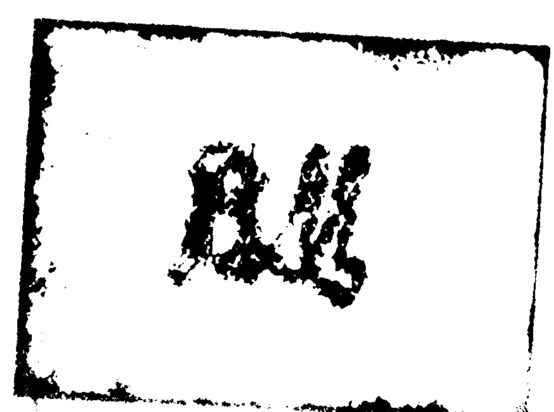


Рис. 7 [illegible] луча при обходе контура [illegible] букв

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